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Thomle et al.

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(54) **DEMAND CONTROL VENTILATION SYSTEM WITH COMMISSIONING AND CHECKOUT SEQUENCE CONTROL**

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(73) Assignee: **Honeywell International Inc.**, Morris Plaines, NJ (US)

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Related U.S. Application Data

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G05D 23/19 (2006.01)
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(52) **U.S. Cl.**
CPC ***F24F 11/006*** (2013.01); ***F24F 12/006*** (2013.01); ***G05B 19/042*** (2013.01); *F24F 2011/0006* (2013.01); *F24F 2011/0091* (2013.01); *F24F 2012/007* (2013.01);
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USPC 700/83, 275, 276, 282; 236/49.3
See application file for complete search history.

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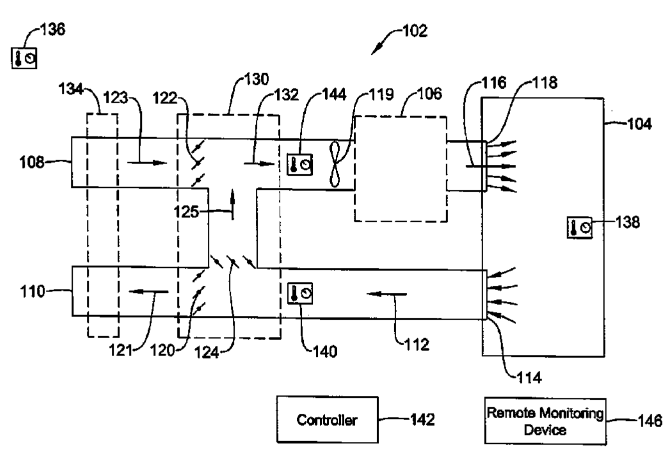
(57) **ABSTRACT**

The disclosure relates to a Demand Control Ventilation (DCV) and/or Economizer system that is capable of drawing outside air into an HVAC air stream. In some instances, the DCV and/or Economizer system may be configured to help perform one or more system checks to help verify that the system is functioning properly. In some instances, the DCV and/or Economizer system may provide some level of manual control over certain hardware (e.g. dampers) to help commission the system. The DCV and/or Economizer system may store one or more settings and or parameters used during the commissioning process (either in the factory or in the field), so that these settings and/or parameters may be later accessed to verify that the DCV and/or Economizer system was commissioned and commissioned properly.

14 Claims, 9 Drawing Sheets



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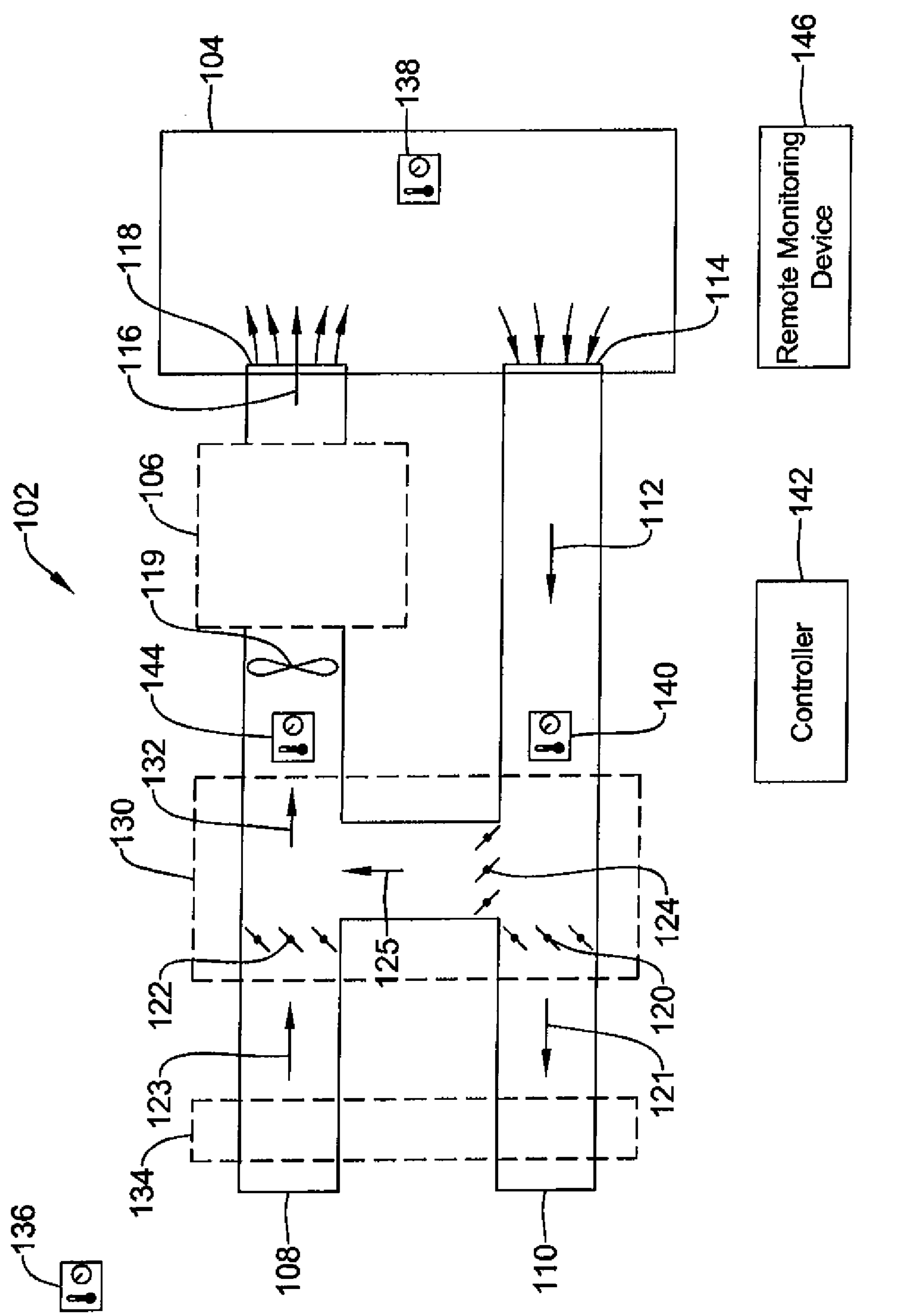
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146
Remote Monitoring Device
Controller

Figure 1

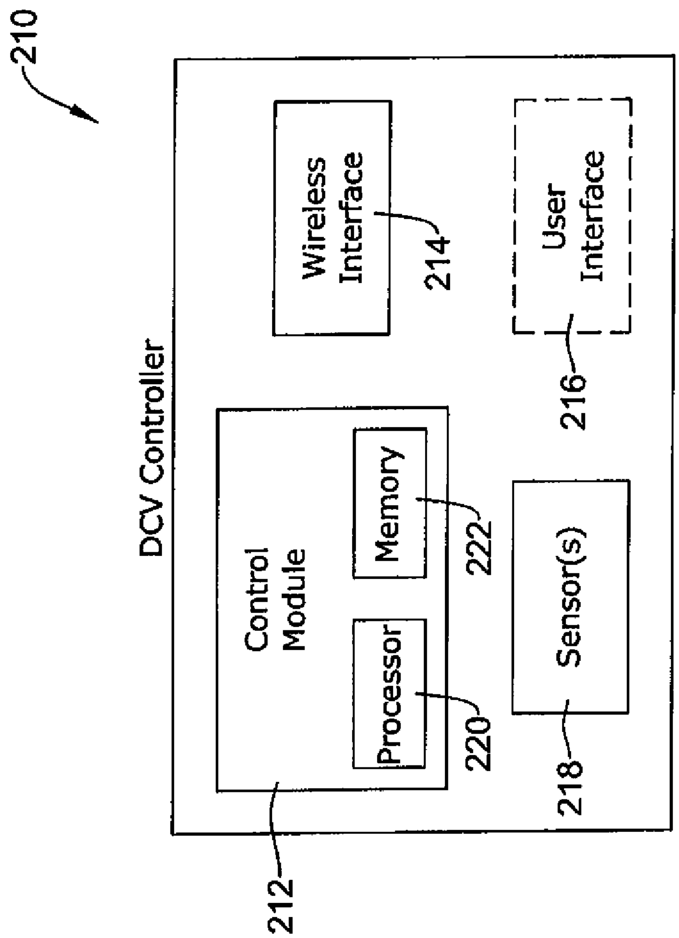
210
DCV Controller
Control Module
Processor
Memory
Wireless Interface
User Interface
Sensor(s)
212
214
216
218
220
222

Figure 2

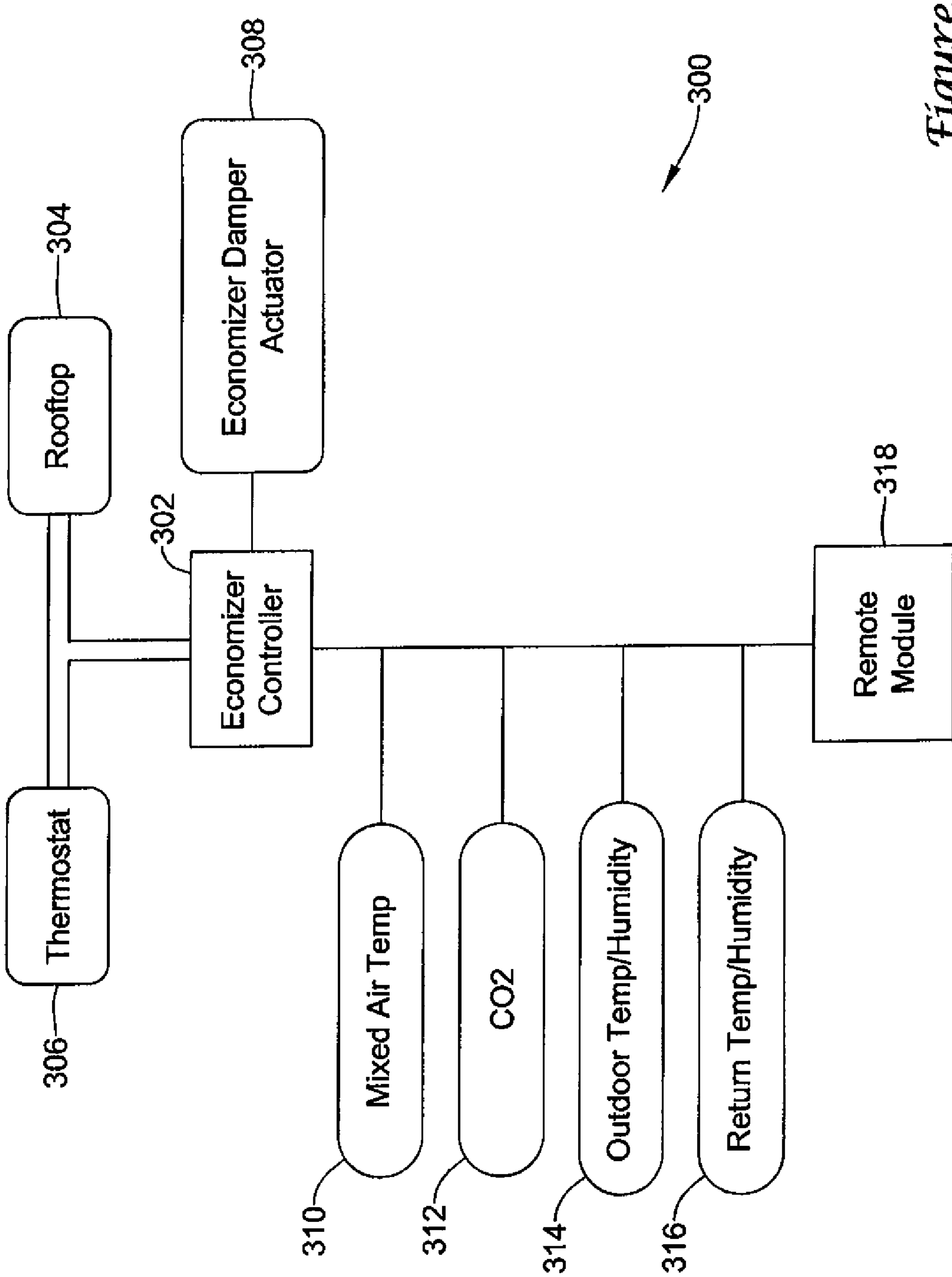
300
302
Economizer Controller
304
Rooftop
306
Thermostat
308
Economizer Damper Actuator
310
Mixed Air Temp
312
CO2
314
Outdoor Temp/Humidity
316
Return Temp/Humidity
318
Remote Module

Figure 3A

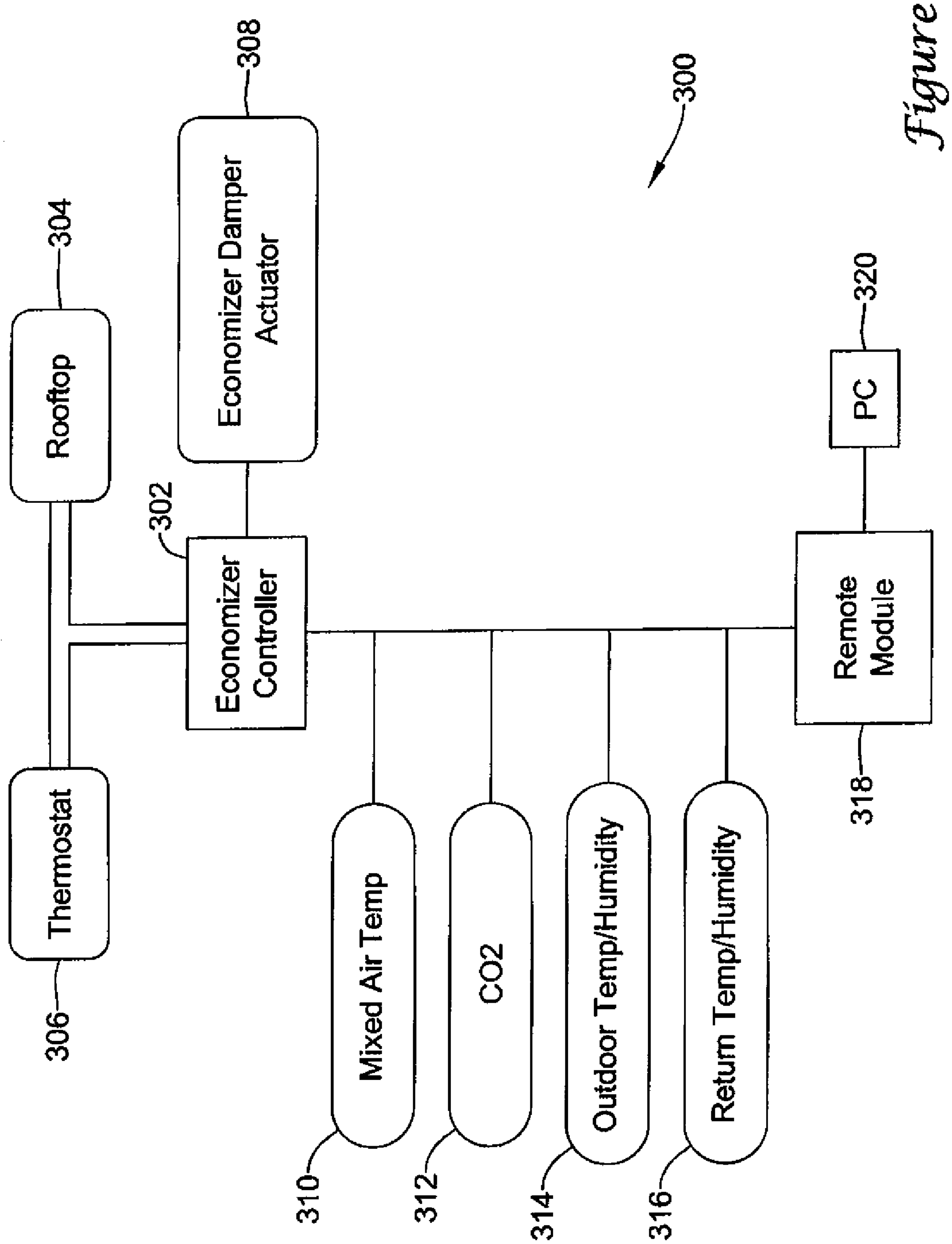
300
Rooftop
304
Economizer Damper Actuator
308
Economizer Controller
302
Thermostat
306
PC
320
Remote Module
318
Mixed Air Temp
310
CO2
312
Outdoor Temp/Humidity
314
Return Temp/Humidity
316

Figure 3B

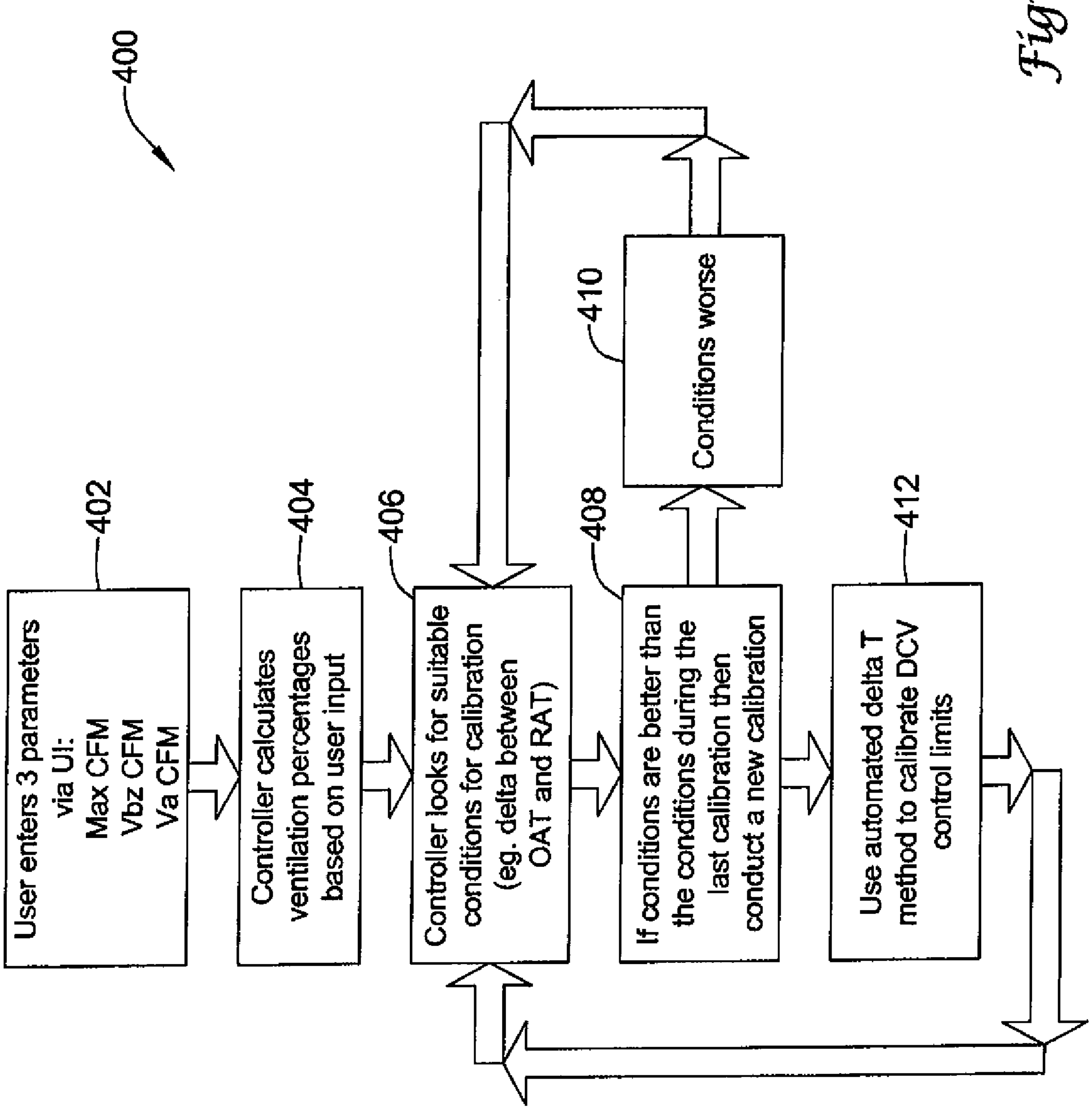
400
402
User enters 3 parameters via UI: Max CFM Vbz CFM Va CFM
404
Controller calculates ventilation percentages based on user input
406
Controller looks for suitable conditions for calibration (eg. delta between OAT and RAT)
408
If conditions are better than the conditions during the last calibration then conduct a new calibration
410
Conditions worse
412
Use automated delta T method to calibrate DCV control limits

Figure 4

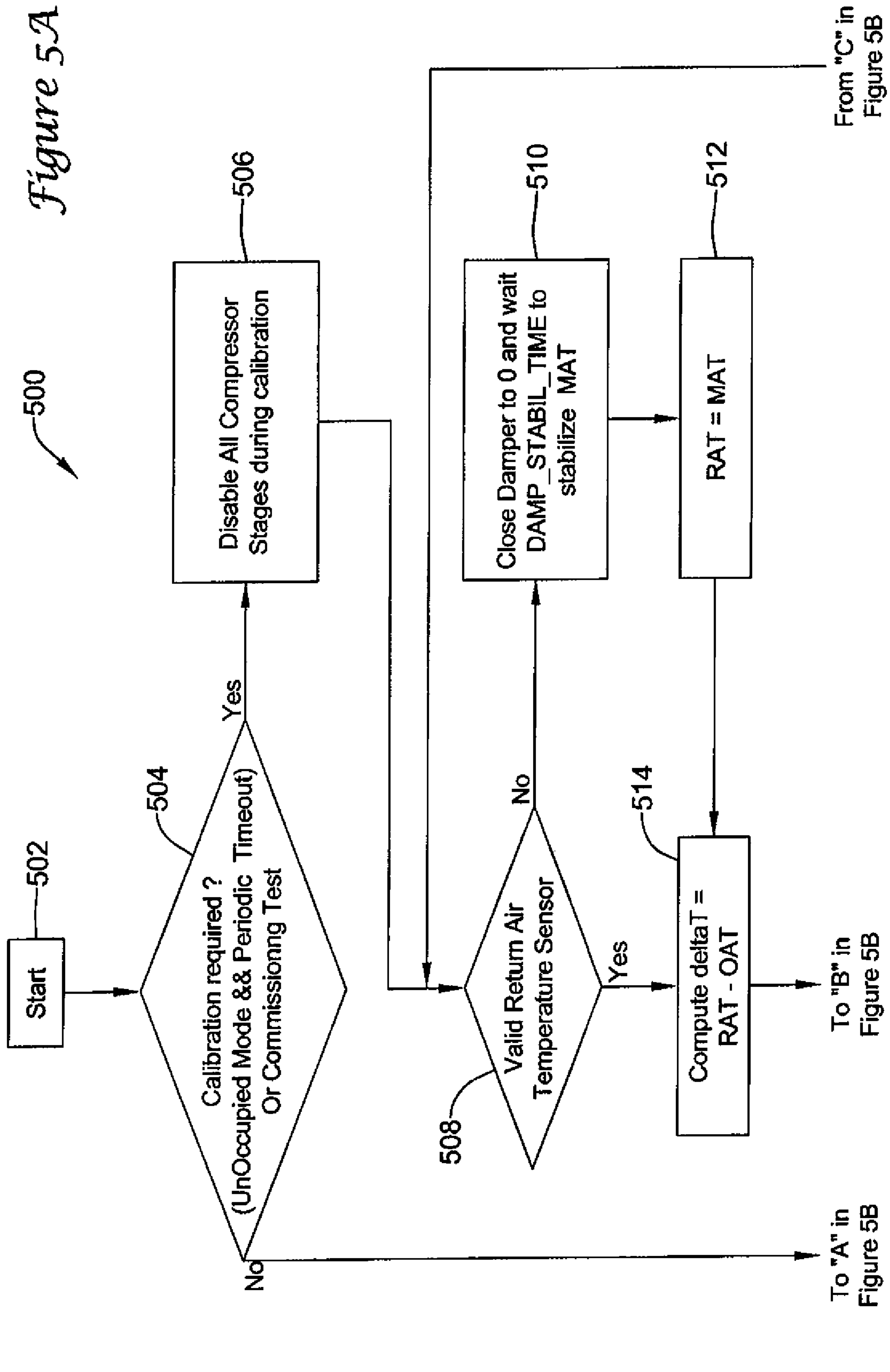
500
Start
502
Calibration required ? (UnOccupied Mode && Periodic Timeout) Or Commissionng Test
504
Yes
No
To "A" in Figure 5B
Disable All Compressor Stages during calibration
506
Valid Return Air Temperature Sensor
508
No
Yes
Close Damper to 0 and wait DAMP_STABIL_TIME to stabilize MAT
510
RAT = MAT
512
Compute deltaT = RAT - OAT
514
To "B" in Figure 5B
From "C" in Figure 5B

Figure 5A

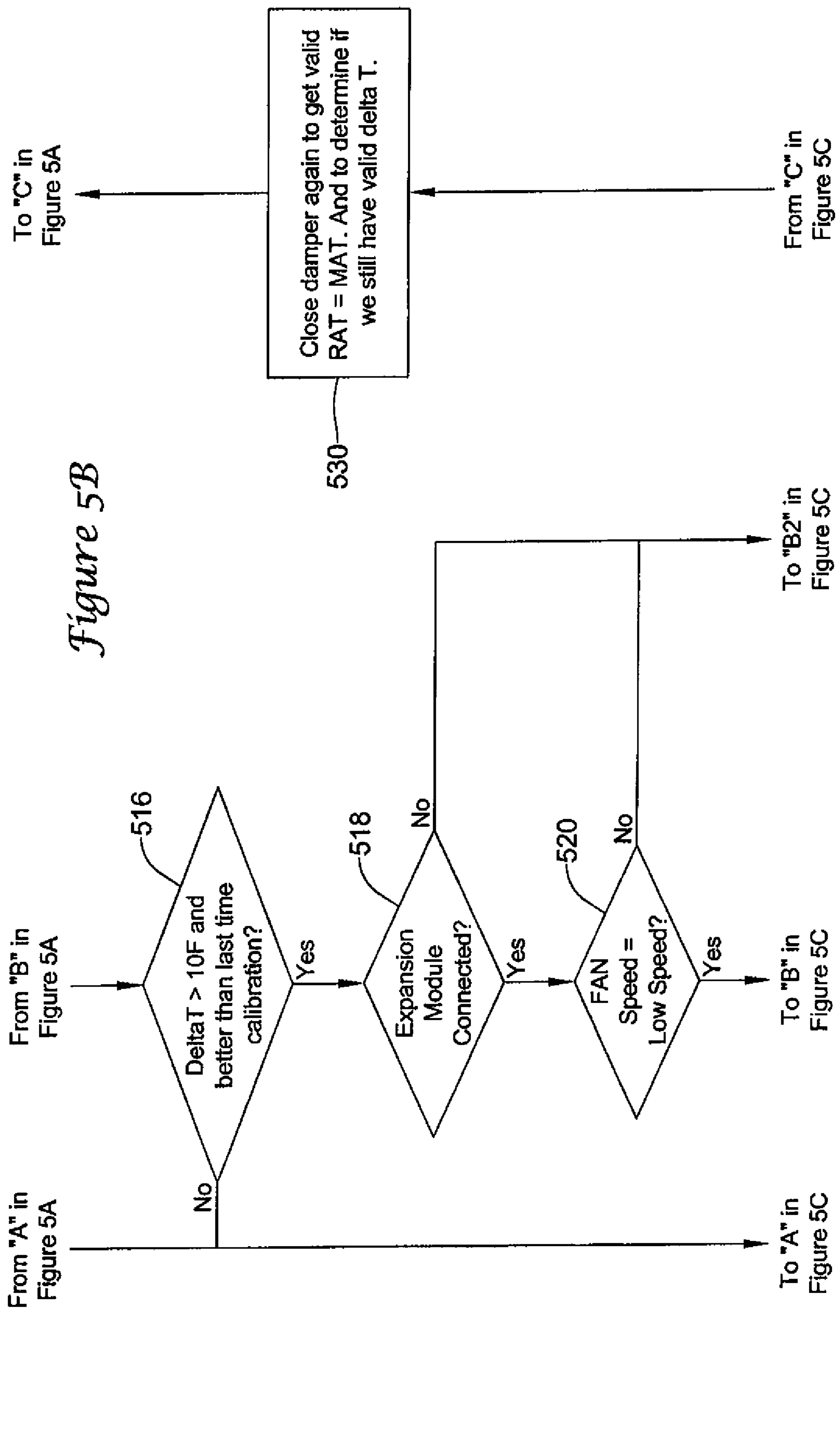
From "A" in Figure 5A
From "B" in Figure 5A
DeltaT > 10F and better than last time calibration?
516
No
Yes
Expansion Module Connected?
518
No
Yes
FAN Speed = Low Speed?
520
No
Yes
To "A" in Figure 5C
To "B" in Figure 5C
To "B2" in Figure 5C
To "C" in Figure 5A
Close damper again to get valid RAT = MAT. And to determine if we still have valid delta T.
530
From "C" in Figure 5C

Figure 5B

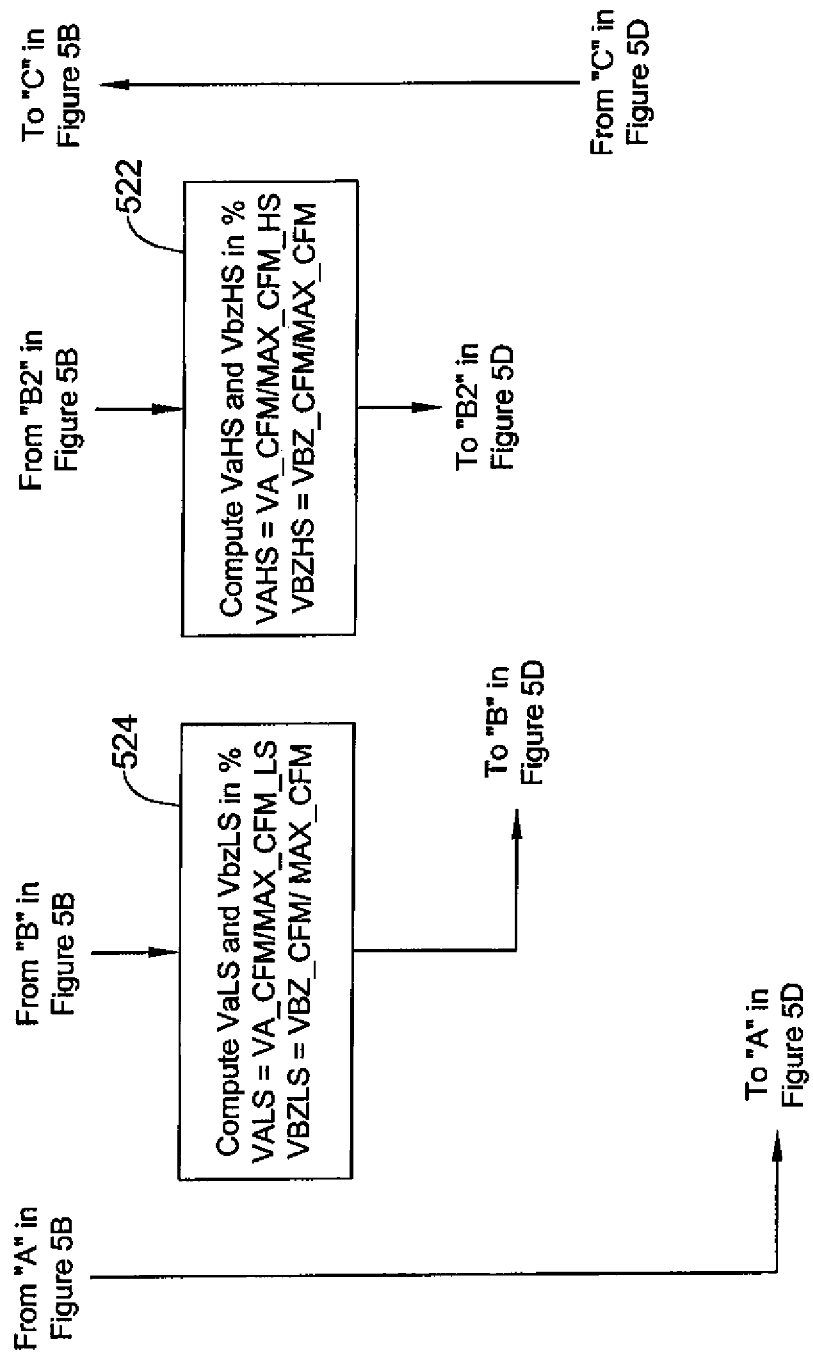
From "A" in Figure 5B
To "A" in Figure 5D
From "B" in Figure 5B
524
Compute VaLS and VbzLS in %
VALS = VA_CFM/MAX_CFM_LS
VBZLS = VBZ_CFM/ MAX_CFM
To "B" in Figure 5D
From "B2" in Figure 5B
522
Compute VaHS and VbzHS in %
VAHS = VA_CFM/MAX_CFM_HS
VBZHS = VBZ_CFM/MAX_CFM
To "B2" in Figure 5D
To "C" in Figure 5B
From "C" in Figure 5D

Figure 5C

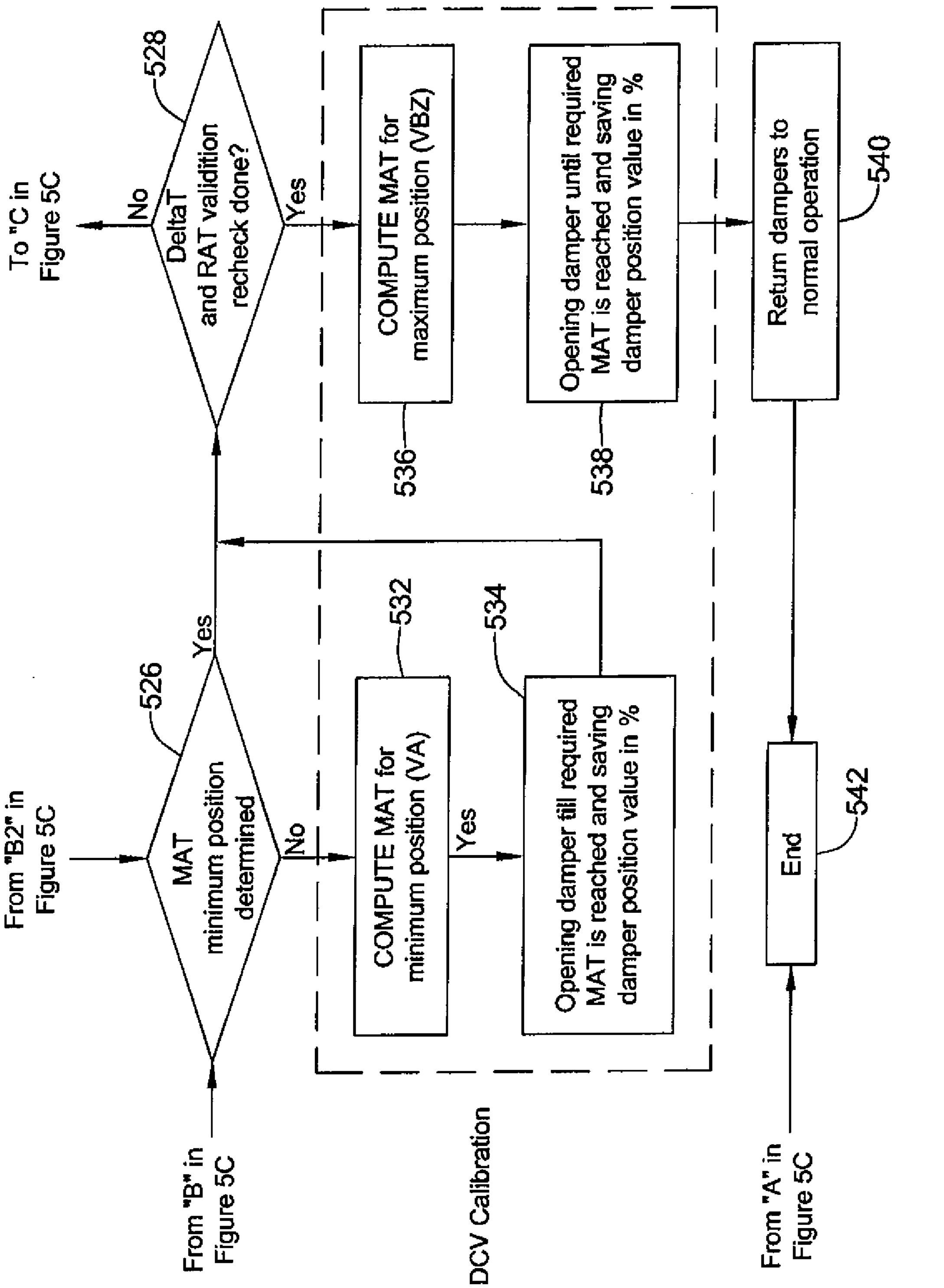
From "B2" in Figure 5C
From "B" in Figure 5C
MAT minimum position determined
526
No
Yes
COMPUTE MAT for minimum position (VA)
532
Yes
Opening damper till required MAT is reached and saving damper position value in %
534
DCV Calibration
To "C in Figure 5C
No
DeltaT and RAT validition recheck done?
528
Yes
COMPUTE MAT for maximum position (VBZ)
536
Opening damper until required MAT is reached and saving damper position value in %
538
Return dampers to normal operation
540
End
542
From "A" in Figure 5C

Figure 5D

DEMAND CONTROL VENTILATION SYSTEM WITH COMMISSIONING AND CHECKOUT SEQUENCE CONTROL

This Application is a Continuation-In-Part (CIP) of U.S. patent application Ser. No. 12/764,431, filed Apr. 21, 2010, and entitled "DEMAND CONTROL VENTILATION SYSTEM WITH REMOTE MONITORING", which is incorporated hereby by reference. This Application is also a Continuation-In-Part (CIP) of U.S. patent application Ser. No. 12/764,415, filed Apr. 21, 2010, and entitled "AUTOMATIC CALIBRATION OF A DEMAND CONTROL VENTILATION SYSTEM", which is incorporated hereby by reference.

TECHNICAL FIELD

The disclosure relates generally to Heating, Ventilation, and Air Conditioning (HVAC) systems for conditioning the air of an inside space of a building or other structure, and more particularly, to economizer and/or demand control ventilation systems.

BACKGROUND

Most modern buildings use some sort of an HVAC system to control the environment conditions inside of the building. Such HVAC systems can be configured to control a number of different environmental conditions including, for example, temperature, humidity, air quality and/or other environmental conditions, as desired. In many HVAC systems, air from the building's inside space is drawn into return ducts and provided back to the HVAC system, where the return air is conditioned and provided back to the inside space. To meet desired ventilation requirements, some HVAC systems include demand control ventilation systems (DCV). Such systems often include an exhaust port for exhausting at least some of the return air to the outside environment, and/or an intake port for bringing fresh air into the HVAC system. In some instances, a damper system is provided to control how much return air is exhausted and/or how much outside air is brought into the building. In many instances, the air supplied by the HVAC system to the inside space can be a mixture of fresh outside air and return air, depending on the conditions.

In some cases, the exhaust and/or intake port can be part of an economizer unit, which in some instances can help provide the demand control ventilation function. That is, in addition to providing a desired level of ventilation to the building, such an economizer may, under certain conditions, act as a first stage of cooling to help decrease energy usage of the HVAC system. In one example, the economizer may draw in cooler outside air to provide essentially "free" cooling during some cooling cycles. Certain dampers, sensors, fans and/or other hardware are often used to provide this functionality.

In many cases, such economizer and/or DCV systems are not properly setup or calibrated during the commissioning process, or are never commissioned at all. In some cases, the commissioning process can be a relatively complicated and time consuming process for a typical installation technician, and therefore, the commissioning process is not always done or done correctly. It would be desirable, therefore, to provide a economizer and/or DCV system that is easier to commission and/or easier to verify that commissioning was properly performed.

SUMMARY

The disclosure relates generally to Heating, Ventilation, and Air Conditioning (HVAC) systems for conditioning the air of an inside space of a building or other structure, and more particularly, to economizer and/or demand control ventilation systems that are capable of drawing outside air into an HVAC air stream. In some instances, the DCV and/or Economizer system may be configured to help perform one or more system checks to help verify that the system is functioning properly. In some instances, the DCV and/or Economizer system may provide some level of manual control over certain hardware (e.g. dampers) to help commission the system. The DCV and/or Economizer system may store one or more settings and or parameters used during the commissioning process (either in the factory or in the field), so that these settings and/or parameters may be later accessed to verify that the DCV and/or Economizer system was commissioned and commissioned properly.

The above summary is not intended to describe each disclosed embodiment or every implementation of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

The following description should be read with reference to the drawings. The drawings, which are not necessarily to scale, depict selected illustrative embodiments and are not intended to limit the scope of the disclosure. The disclosure may be more completely understood in consideration of the following description of various illustrative embodiments in connection with the accompanying drawings, in which:

FIG. **1** is a schematic diagram showing an illustrative HVAC system of a building including an economizer/demand control ventilation (DCV) system;

FIG. **2** is block diagram of an illustrative demand control ventilation (DCV) and/or economizer controller;

FIGS. **3**A and **3**B are block diagrams of an illustrative HVAC system utilizing DCV and/or economizing control;

FIG. **4** is a block diagram of an illustrative damper calibration method; and

FIGS. **5**A-**5**D show a block diagram of another illustrative damper calibration method.

While the invention is amenable to various modifications and alternative forms, specifics thereof have been shown by way of example in the drawings and will be described in detail. It should be understood, however, that the intention is not to limit aspects of the invention to the particular embodiments described. On the contrary, the intention is to cover all modifications, equivalents, and alternatives falling within the spirit and scope of the invention.

DESCRIPTION

As used in this specification and the appended claims, the singular forms "a", "an", and "the" include plural referents unless the content clearly dictates otherwise. As used in this specification and the appended claims, the term "or" is generally employed in its sense including "and/or" unless the content clearly dictates otherwise.

The following detailed description should be read with reference to the drawings in which similar elements in different drawings are numbered the same. The detailed description and the drawings, which are not necessarily to scale, depict illustrative embodiments and are not intended to limit the scope of the invention. The illustrative embodiments depicted are intended only as exemplary. Selected features of any illustrative embodiment may be incorporated into an additional embodiment unless clearly stated to the contrary.

FIG. **1** is a schematic diagram showing an illustrative Heating, Ventilation, and Air Conditioning (HVAC) system **102** of a building **104**. The HVAC system **102** may include a Demand

Control Ventilation (DCV) and/or Economizer system **130**. The building **104** may be a residential, commercial, or any other suitable building. The HVAC system **102** may include an HVAC unit **106**, which in some cases may include one or more heating and/or cooling units. In some embodiments, the HVAC unit(s) **106** may be positioned on a rooftop (as in some commercial buildings) whereas in other embodiments, the HVAC unit(s) may be located within the building. In the illustrative embodiment shown, the HVAC system **102** includes an DCV and/or Economizer **130** upstream of the HVAC unit **106**. The DCV and/or Economizer **130** may include an outside air intake **108** and/or an exhaust vent **110**. A return air stream **112** is shown for drawing return air from the inside space of the building **104** through one or more return registers **114**. The illustrative HVAC system **102** includes a fan **119**, which may be a multiple or infinite speed fan, which can be controlled to induce an air flow through the HVAC unit **106** and to the building **104** as shown at **116** through one or more supply registers **118**. In some cases, the DCV and/or Economizer **130** may includes its own fan.

As shown, the DCV and/or Economizer system **130** of the HVAC system **102** may employ one or more dampers within the various ducts of the DCV and/or Economizer system **130** to control air flows. In some instances, these dampers may include an exhaust damper **120** to regulate the fraction of the return air stream **112** that is exhausted **121** from the building **104**, an intake damper **122** to regulate the flow of an incoming outside air stream **123** into the building **104**, and/or a return damper **124** to regulate the flow of the retained return air stream **125** to mix with the incoming outside air stream **123**. In some cases, the dampers **120**, **122**, and/or **124** may be mechanically coupled together to open and close in a coordinated manner, but this is not required. For example, in some illustrative embodiments, dampers **120** and **122** may open and close together or in sequence, and damper **124** may open and close in an opposite manner to dampers **120** and **122**. When so provided, when damper **122** is opened to allow more of the outside air stream **123** into the building **104**, damper **120** may also open to allow a similar amount of the return air stream **112** to be exhausted **121** from the building **104**. The return air damper **124** may close as the dampers **120** and **122** open. This arrangement may help balance the pressure inside the HVAC system **102** and building **104**. In some illustrative embodiments, more or fewer of the dampers **120**, **122**, and **124** may be employed, but the teachings of this disclosure may be applied advantageously to any suitable HVAC system.

In some embodiments, the Demand control ventilation (DCV) system, including the dampers **120**, **122**, **124** and/or associated duct work, may be included in an economizer unit, but this is not required. Under some conditions, such an economizer unit may be used to provide a first stage of free cooling by mixing cooler incoming outside air **123** with the sometimes warmer retained return air **125** to provide a cooler mixed air stream **132** to the cooling coils of the HVAC unit **106**. Note that in the present disclosure, "return air" may refer to the return air stream **112**, before it has been (possibly) divided into an exhaust air stream **121** and a retained return air stream **125**, and in other cases, "return air" or "return air stream" may refer to the retained return air stream, regardless of whether the retained return air stream includes the entire return air stream **112** or only a fraction thereof. It generally will be clear from context what "return air" refers to, and in the case of referring to the contribution of inside air to the mixed air stream **132**, it generally is to be understood that the retained return air stream **125**, which originates from the return air stream **112**, may be referred to as "return air."

In some instances, the HVAC system **102** may include a heat exchanger generally shown at **134** to transfer heat energy between the incoming outside air stream **123** and the exhausted air stream **121**, which may be useful under some operating conditions.

Decisions for when and how to use the DCV and/or Economizer **130** may depend on strategies that consider current and/or past conditions of outside air and/or indoor air. In some instances, the HVAC system **102** of FIG. **1** may include one or more outdoor air sensors **136** for measuring one or more parameters of the outside air. Current economizer strategies are typically based on dry bulb temperature, enthalpy, a combination of the two, or a sensed enthalpy that approximates the two. These strategies generally base a decision to economize (e.g., whether to draw in outside air in amounts greater than those needed to meet Demand Control Ventilation requirements) on the outside air temperature or enthalpy and whether there is a need to cool the inside space of the building **104**.

The HVAC system of FIG. **1** may include one or more inside air sensors **138** for measuring one or more parameters of the air of the inside space of the building **104**. Alternatively, or in addition, one or more return air stream sensors **140** may be provided to measure parameters of the air of the inside space, given that the return air stream **112** is drawn from the inside space of the building **104**. In some cases, a mixed air sensor **144** may be provided. Any of inside **138**, return **140**, mixed **114**, and outside **136** sensors may be configured to determine one or more air parameters of interest, such as dry bulb temperature, wet bulb temperature, dew point (i.e., dew point temperature), relative humidity, and/or enthalpy (i.e., specific enthalpy), to name a few. Notably, these air parameters are not all independent. With appropriate assumptions (e.g., ideal gases, etc.), their interrelationship may be expressed through psychrometric equations and represented graphically, for example on a psychrometric chart, or numerically as desired. Some desired air parameters may be obtained from measurements of two other appropriately chosen air parameters. For example, dew point and/or enthalpy may be calculated from measured values of dry bulb temperature and relative humidity. In some illustrative embodiments, any of inside **138**, return **140**, mixed **114**, and/or outside **136** sensors may be configured to measure or determine two or more air parameters selected from a set of parameters such as dry bulb temperature, dew point, relative humidity, and/or enthalpy.

A controller, such as controller **142**, may be provided to control the HVAC system **102**. Controller **142** may be any suitable controller. Controller **142** may be a controller for the entire HVAC system **102**, or any appropriate subset or subsets of the HVAC system **102** such as the DCV and/or Economizer **130**. Physically, it may be a stand-alone unit or units, or it may be integrated with hardware, such as with DCV and/or Economizer **130**. Controller **142** may be configured to receive information from any suitable source, such as the inside **138**, return **140**, mixed **144**, and/or outside **136** sensors, and it may be configured to issue commands to any appropriate component of the HVAC system **102**, such as dampers **120**, **122**, **124**, fan **119**, HVAC unit **106**, etc. It is contemplated that controller **142** may be configured and programmed in any suitable manner.

In the event that controller **142** is integrated with hardware or located, for instance with a rooftop unit, it may difficult to determine if the HVAC system **102** and/or DCV and/or Economizer **130** is functioning properly without physically visiting the controller **142**. In some instances, a remote monitoring device, such as remote monitoring device **146**, may be provided to allow the building owner and/or building occupant to monitor the HVAC system **102** and/or DCV/Economizer **130** without physically visiting the controller **142** or the HVAC unit(s) **106**. It is contemplated that in some embodiments, remote monitoring device **146** may be located within building **104**, or other location which allows for convenient access to the remote monitoring device **146**. In some instances, the remote monitoring device **146** may provide alerts and system faults in real time to the user. In some embodiments, remote monitoring device **146** may allow remote configuration of the HVAC system **102** and/or DCV/Economizer **130** in order to change control points or other parameters without physically visiting the system **102** as discussed in more detail with respect to FIGS. **2**, **3**A and **3**B. In some embodiments, the controller **142** itself may be located within building **104**, or other location which allows for convenient access to the controller **142**, but this is not required or even desired in all embodiments. This may, however, reduce the need for a separate remote monitoring device **146**.

FIG. **2** is a block diagram of an illustrative DCV and/or Economizer controller **210**, which may be used in conjunction with the HVAC system of FIG. **1**. While controller **210** may be described as DCV and/or Economizer controller **210**, it should be understood the DCV control system and/or economizer system may function independently of one another and may function on separate control loops, if both are present. Further, while the HVAC system **102** may be described as having an economizing function and demand control ventilation capabilities, it should be understood that one may be present without the other. In the illustrative embodiment, the controller **210** may include a control module **212**, a wireless interface **214**, an optional user interface **216**, and one or more sensors **218**. However, this is just one example of a suitable controller. In some cases, the one or more sensors **218** may include a temperature sensor, a humidity sensor, a ventilation sensor, an air quality sensor (e.g. CO_2 sensors), and/or any other suitable HVAC building control system sensor, as desired. Temperature sensor(s) may be provided to sense the indoor, outdoor temperatures and/or mixed air temperatures. Likewise, humidity sensor may be provided to sense the humidity of the indoor, outdoor and/or mixed air. As illustrated, the one or more sensors **218** may be included with the Controller **210**, such as within a housing of Controller **210**. However, it is contemplated that one or more sensors **218** may be located remote from the Controller **210**, but in communication therewith, if desired.

Control module **212** of the illustrative Controller **210** may be configured to help control the comfort level (i.e. heating, cooling, ventilation, and/or air quality, etc.) of at least a portion of the building or structure **104** by controlling one or more dampers **120**, **122**, **124** and/or activating one or more HVAC components **106**, as illustrative in FIG. **1**. In some instances, control module **212** may include a processor **220** and a memory **222**. Control module **212** may be configured to control and/or set one or more HVAC functions, such as, for example, HVAC schedules, temperature setpoints, humidity setpoints, trend logs, timers, fan speeds, damper positions, environment sensing, and/or other HVAC functions or programs, as desired. In some cases, control module **212** may be used to configure one or more settings of the HVAC controller, such as, for example, HVAC controller schedules including ventilation schedules, temperature setpoints, humidity setpoints, trend logs, timers, fan speeds, damper positions, environment sensing, HVAC controller programs, user preferences, and/or other HVAC controller settings, as desired. In the illustrative embodiment, control module **212** may help control the comfort level of at least a portion of the building or structure using the temperature sensed by temperature sensor of the one or more sensors **218**, when provided.

A memory **222** may be used to store any desired information, such as the aforementioned HVAC schedules, temperature setpoints, humidity setpoints, trend logs, timers, fan speeds, damper positions, environmental settings, and any other settings and/or information as desired. Control module **12** may store information within memory **222** and may subsequently retrieve the stored information. Memory **222** may include any suitable type of memory, such as, for example, random-access memory (RAM), read-only member (ROM), electrically erasable programmable read-only memory (EEPROM), Flash memory, or any other suitable memory, as desired. In some instances, memory **222** may store one or more control programs for execution by the processor **220**.

When present, wireless interface **214** of the Controller **210** may be configured to wirelessly communicate (i.e. transmit and/or receive signals) with a wireless interface of one or more HVAC controllers (and/or HVAC components **106**). For example, wireless interface **214** may be configured to communicate with a wireless interface of an HVAC controller and send and/or receive signals corresponding to, for example, a temperature sensed by temperature sensor, a humidity sensed by the humidity sensor, heat and/or cool set points, ventilation settings, indoor and/or outdoor air temperatures, equipment status, scheduling, trend logs, and/or any other suitable information and/or data. It is contemplated that the wireless interface **214** may include, for example, a radio frequency (RF) wireless interface, an infrared wireless interface, a microwave wireless interface, an optical interface, and/or any other suitable wireless interface, as desired. While a wireless interface **214** is shown in FIG. **2**, it is contemplated that a wired interface may be used instead, or in addition to, the wireless interface **214**.

The optional user interface **216** may be any suitable interface that is configured to display and/or solicit information as well as permit a user to enter data and/or other settings, as desired. In some cases, user interface **216** may allow a user or technician to program and/or modify one or more control parameters of Controller **210**, such as programming a set point, a time, an equipment status and/or parameter, as desired. In some instances, the user interface **216** may include a touch screen, a liquid crystal display (LCD) panel and keypad, a dot matrix display, a computer, buttons, one or more LED's and/or any other suitable interface, as desired. In one example, at least some of the parameters and/or settings may be transmitted to the Controller **210** via wireless interface **214**, but this is not required or even desired in all embodiments. In some instances, user interface **216** may be configured to alert the user to system faults occurring in the system using, for example, audio and/or visual alerts. In some cases, Controller **210** may only control the DCV and/or Economizer system, and not the HVAC system more generally.

In some embodiments, the HVAC system **102**, such as illustrated in FIG. **1**, may include a Controller **210** that is programmed to control ventilation to the building **104** based on actual occupancy using carbon dioxide (CO_2) sensors. Alternatively, or in addition, Controller **210** may be programmed to control ventilation to the building **104** based on a ventilation schedule, or a combination of actual occupancy and a ventilation schedule. In either case, it contemplated that controller **210** may allow the ventilation rate to vary based on actual or scheduled occupancy, rather than requiring a maximum ventilation rate at all occupied times. Because buildings are rarely, if ever, at maximum occupancy at all times, Controller **210** may, if desired, provide substantial energy and/or cost savings by not requiring the ventilation rate to be at the maximum ventilation rate during all occupied time periods.

FIGS. **3**A and **3**B are block diagrams **300** illustrating how an illustrative DCV and/or economizer controller **302** may interact with the various components of the HVAC system **102**. This is, however, just one example. In the example shown, a programmable controller, such as a thermostat **306**, may be provided to control the HVAC unit(s) **106**. The thermostat **306** may be in communication with the HVAC unit(s) **106**, which in some instances may be rooftop unit(s) **304**, however it is contemplated the HVAC unit(s) **106** may be located within the building or at some other location. The thermostat **306** may be configured to be programmable such that the building may be heated and/or cooled according to a desired schedule. In some instances, the thermostat **306** may communicate with the rooftop (or other) unit(s) **304** to turn the unit(s) **304** on and off as needed. In some embodiments, the thermostat **306** may be hardwired to the rooftop (or other) unit(s) **304** while in other embodiments, the thermostat **306** may be in wireless communication with the rooftop unit(s) **304**.

The thermostat **306** may be part of or in communication with a DCV and/or economizer controller **302**. As discussed above, DCV and/or economizer controller **302** may be programmed to control ventilation to the building **104** based, for example, on actual occupancy using carbon dioxide (CO_2) sensors. For example, in addition to operating the HVAC unit(s) to provide a desired temperature, the HVAC system **102** may also be configured to bring a certain amount of fresh ventilation into a building as set out in, for example, building codes. When DCV and/or Economizer controller **302** is so provided, DCV and/or Economizer controller **302** may communicate with damper actuator **308** to selectively open and close dampers based on the amount of ventilation needed. For example DCV and/or Economizer controller **302** may receive a signal from a CO_2 sensor **312**. When the amount of CO_2 in the building reaches a threshold level, the DCV and/or Economizer controller **302** may relay a signal to the damper actuator **308** to open a damper (for example, damper **122** in FIG. **1**) to provide more fresh air to the building. Likewise, when the amount of CO_2 in the building falls below a threshold level, the DCV and/or economizer controller **302** may relay a signal to the damper actuator **308** to close or partially close a damper (for example, damper **122** in FIG. **1**) to minimize the amount of conditioned air that is lost to atmosphere. In some instances, the damper actuator **308** may include a direct coupled actuator (DCA) such that the controller **302** may communicate digitally with the actuator **308**. DCV and/or economizer controller **302** may also receive signals from other sensors such mixed air temperature **310**, outdoor air temperature and/or humidity **314**, and return air temperature and/or humidity **316** sensors. These parameters may be used to determine, for example, whether or not the DCV and/or Economizer controller **302** will draw in outside air in amounts greater than those needed to meet Demand Control Ventilation requirements.

In some instances, the DCV and/or Economizer controller **302** may be in communication with a remote monitoring device **318**, or may be incorporated into the remote monitoring device **318**, but this is not required or even desired in all embodiments. In one illustrative example, remote monitoring device **318** may display operational parameters which may allow the user to monitor the HVAC system **102** remotely. For example, the remote monitoring device **318** may indicate that status of an HVAC unit (e.g. on/off), if free cooling (economizer mode) is available, DCV status (e.g. on/off), temperature/humidity readings from the various sensors, CO_2 levels (parts per million, ppm), fan speed (e.g. low/high), building occupancy, etc. The remote monitoring device **318** may be further configured to allow a user to input various parameters such as CO_2 threshold setpoints, temperature setpoints, percent of ventilation at high/low fan speeds, minimum and maximum calibration ventilation flow rates at one or more calibration damper positions—sometimes at various fan speeds, etc., to be provided to the DCV and/or economizer controller **302**. The remote monitoring device **318** may be further configured to provide a user with system alerts and/or system faults. For example, the remote monitoring device may be able to alert the user to a malfunction within the rooftop unit **304** that the user may otherwise be unaware of. This may allow a user to maintain a DCV system/economizer **130** more effectively. The remote monitoring device **318** may be configured to provide an alert such as, but not limited to, an audible alarm, an indicator light, and/or display and/or send a message when a fault has been detected. The remote monitoring device **318** may be in communication with the controller **302** via a wired, wireless or any other suitable interface, as desired. It is contemplated that in some instances the DCV and/or economizer controller **302** may be capable of displaying operational parameters, receiving user inputs, and/or providing alerts.

As illustrated in FIG. **3**B, in some instances, the remote monitoring device may be in communication with a computer **320**, or other data logging system. Such a data logging system may allow a user to monitor the trends of the system **102**, which might help a user more effectively program and/or operate the HVAC system **102**. For example, the user may be able to retrieve historical system data such as when the system **102** was able to function in economize and/or demand control modes. This may help the user and/or the controller **302** to better predict necessary system maintenance or when calibration of the system might be warranted.

In one illustrative embodiment, and prior to operating controller **302**, the system **102** may be calibrated based on a minimum and a maximum desired ventilation rate by, for example, changing the damper positions and/or changing a fan speed (e.g. of fan **119**) between a low and a high setting. In some instances, the HVAC system **102** may be automatically calibrated from time to time, or in some cases, effectively continuously calibrated. As used herein, calibration may refer to, among other things, calibration of the system during initial installation of the system, or a re-calibration of the system during a subsequent system checkout (e.g. to help ensure proper functioning after the initial calibration). In some cases, the controller **302** may be calibrated at both a maximum fan speed and a minimum fan speed, for both a code mandated ventilation rate required for the building **104** during maximum occupancy (hereinafter Vbz) and for a code mandated minimum ventilation rate required for building material out-gassing (hereinafter Va).

The calibration/commissioning process may include calibrating minimum (Va) and maximum (Vbz) damper position settings based on desired minimum and maximum ventilation rates. These damper settings are sometimes called out in the HVAC system design documents for the building supplied by an engineering firm that designed the system, and may be expressed as a percentage of ventilation (or percentage of fresh air in the mixed air stream). To help program the system's **102** minimum and maximum ventilation rates, temporary or permanent calibration sensors may be placed at the outside air intake **108**, the return air duct **112** and/or at the mixed air duct **132**. In one example, temperature may be used to measure ventilation rate. In some cases, a minimum differential of 10 degrees Fahrenheit is desired between the return air temperature (RAT) and the outdoor air temperature (OAT) to conduct a calibration. Once this condition is met, the following readings may be collected, and the readings may be used as inputs to Equation 1 below:

$$(OAT-RAT)\times\%\ Ventilation+RAT=MAT \qquad \{Equation\ 1\}$$

where OAT=Outside air temperature, RAT=Return air temperature, and MAT=Mixed air temperature. During the calibration, the outdoor and/or return air dampers may be repositioned by the controller until the correct ventilation percentage (% Ventilation) is achieved for each minimum and maximum ventilation settings. The controller **302** may then be programmed to interpolate an intermediate ventilation rate, depending on actual, sensed or scheduled occupancy, by modulating between these two calibrated damper positions (or extrapolating beyond the values). This calibration may be performed for each fan speed of fan **119** of the HVAC system **102**.

In some cases, the controller **302** may be programmed to use a mixed air temperature sensor to determine a return air temperature and/or an outside air temperature. In one example, and to determine the fresh air temperature, the controller **302** may close return air damper **124** and open fresh air damper **122** (see FIG. **1**). Under these conditions, the mixed air stream will be mostly fresh outside air, and thus once stabilized, the mixed air temperature sensor **144** will sense the temperature of the fresh outside air. Likewise, to determine the return air temperature, the controller **302** may close fresh air damper **122** and open return air damper **124** (see FIG. **1**). Under these conditions, the mixed air stream will be mostly return air, and thus once stabilized, the mixed air temperature sensor **144** will sense the temperature of the return air. This procedure may be used by the controller **302** to help determine the return air temperature and/or the outside air temperature when no return air temperature sensor and/or outside air temperature sensor are provided, or have failed.

In some instances, it may be desirable for a technician commissioning the system **130**, an original equipment manufacturer (OEM), and/or an installer to test the DVC and/or Economizer **130** upon installation, system start-up, or on-demand, as desired. In some illustrative embodiments, the DCV and/or Economizer system **130** may be configured to perform system checks to help verify that the system was commissioned correctly and is/was functioning properly. In some cases, the DCV and/or Economizer system may include a controller that provides support for some level of self-testing including, for example, proving that one or more dampers move to certain open and closed positions under certain conditions, proving that one or more sensors are functioning properly, proving that one or more fans (if present) can be energized properly, and/or perform any other suitable self-test function, and provide confirmation to the user. In some instances, the settings used during the commissioning process of the DCV and/or Economizer system **130** (either in the factory or in the field) may be stored in a memory, such as memory **222** of the controller, where they can be later downloaded to verify that the particular DCV and/or Economizer system **130** was set up correctly. In some instances, it may be desirable to be able to verify damper moves

In some embodiments, the a controller **302** may be configured such that a user can test one or more of the DCV and/or Economizer **130** functions (e.g. damper moves, mechanical cooling, etc) through a user interface (e.g. a user interface **216**), through one or more physical terminal(s), through a wireless interface (e.g. a wireless interface **214**), or through any other suitable interface, as desired. In one example, the user may be able to link a portable device such as, but not limited to, a laptop computer, a personal digital assistant (PDA), or a cellular phone (smart phone), directly to the controller **302** to initiate one or more system tests. In some embodiments, the controller **302** may provide audio and/or visual feedback (e.g. beeps and/or LEDs) to the user to help verify that the system **130** was commissioned properly and/or is functioning properly. Additionally, or alternatively, the controller **302** may provide audio and/or visual feedback to indicate the system is not functioning properly or that an error has occurred. In some instances, the controller **302** may provide additional feedback, such as the set damper positions, and/or other system control parameters. In some instances, the controller **302** may be configured to perform a system self-test upon system start-up. Alternatively, or in addition, the controller **302** may be configured to perform a system self-test on demand, or at a user's prompting. A result of the self-tests may be output to a user via a user interface and/or stored in a memory for later viewing.

In some instances, the controller **302** may includes a test mode, wherein in the test mode, a user can independently control various aspects of the CV and/or Economizer **130** system, such as damper position, mechanical cooling mode, fan operation, etc.

In some instances, the controller **302** may be configured to provide feedback, including such things as setup operating parameters provided during a commissioning process, through a communication link to a portable device such as, but not limited to a personal digital assistant (PDA), a cellular phone (smart phone), or a laptop computer. In other instances, the controller **302** may be configured to wirelessly communicate with a remote monitoring device and/or thermostat. In yet other instances, the controller **302** may communicate such parameters with a local user interface that is local to the DCV and/or Economizer **130** system (e.g. on the roof top).

The controller **302** may be further configured to store data and settings compiled during the commissioning of the stem, for verification of proper commissioning of the system. For example, in some instances, the controller **302** may be configured to store current set and reset damper positions, a maximum and/or minimum damper position, air flow parameters, the date of commissioning, a person or company name that performed the commissioning, and/or other DCV and/or economizer parameters. This information may be accessed at a later date by, for example, a building owner or utility representative to verify the DCV and/or economizer system **130** was properly commissioned and is/was functioning. It is contemplated that this information may be transferred to a device used to initiate the system test and/or commissioning. In some instances, the OEM (Original Equipment Manufacturer) may perform some system checks and/or commissioning of the economizer **130** (or other equipment) before shipment, to help ensure that the equipment will meet the desired specifications. The OEMs may store these system checks and/or commissioning parameters in a memory, such as a non-volatile memory in a controller **302**, which may help certify that the economizer **130** was in fact commissioned and/or functioning properly prior to shipment. The OEM may be able to retrieve the data from the controller **302** and maintain the information within their own records for later access. In some instances, the DCV and/or economizer **130** may be added or retrofitted to an existing rooftop unit (or other system). When so provided, the commissioning data obtained during the installation of the DCV and/or economizer system **130** may be recorded by the installer in a memory such that the data can be subsequently recalled to help verify that the system **130** was correctly commissioned and installed.

In some instances, it may be desirable for the controller **302** to automatically calibrate the DCV and/or economizer system **130**, but this is not required. FIG. **4** is a flowchart of an illustrative method **400** for automatically calibrating a DCV and/or economizer system **130**. A user may input parameters into controller **302** relating to the ventilation requirements **402** of the particular system **102**/building **104**. The user may enter the parameters via a user interface (UI), sometimes directly coupled to the controller **302**, or into a remote user interface, such as remote monitoring device **318**. For example, the user may enter the maximum ventilation rate the system is capable of providing (e.g. in cubic feet per minute, CFM), the code mandated ventilation rate required for the building **104** during maximum occupancy, Vbz, and the code mandated minimum ventilation rate required for building material out-gassing, Va. In some cases, default values are provided for each of these parameters.

Based on the parameters, the controller **302** may calculate the ventilation percentages **404** for Vbz and Va. The controller **302** may then monitor the signals from outdoor temperature sensor **314** and return air temperature sensor **316** for suitable conditions for calibration, as shown at block **406**. For example, the controller **302** may monitor the temperature difference between the outdoor air and the return air for a differential of at least **10** degrees Fahrenheit. Once such a condition is detected, and in some cases, the controller **302** may compare the current conditions to the conditions during the previous calibration **408**. If the current conditions are better than the conditions during the previous calibration (e.g. a larger temperature differential), the controller **302** may automatically recalibrate **412** the system **130** based on the current conditions. If the current conditions are worse than the conditions during the previous calibration (e.g. a smaller temperature differential), the controller **302** may do nothing **410** and continue monitoring the temperature sensors **314**, **316** for more ideal conditions for calibration at block **406**.

In some embodiments, the controller **302** may automatically calibrate the DCV and/or economizer system **130** from time to time. When so provided, the DCV and/or economizer system **130** may continually optimize itself for changing environmental and/or equipment conditions. In some instances, the controller **302** may be caused, either during system boot-up or in a test or calibration mode, to perform a complete system checkout in order to help ensure that the HVAC system **102** is functioning properly.

FIGS. **5A-5D**, in combination, show a flowchart of another illustrative method for calibrating the damper positions. In some cases, the damper positions may be calibrated during the initial installation of the HVAC system **102**, and/or automatically from time to time during normal system operation. Referring to FIG. **5A**, the damper calibration process **500** may begin **502** during, for example, an initial system set-up, during an automatic calibration process, and/or at user prompting (e.g. the user activates a calibration mode in the controller **302**). In some embodiments, the DCV and/or economizer controller **302** may continually monitor the environmental conditions, and when the environmental conditions are suitable for a recalibration, the controller **302** may run a calibration algorithm.

Referring to block **504**, the controller **302** may first determine if the DCV and/or economizer system **130** requires calibration **504**. If not, the controller **302** does nothing and the damper calibration process is ended at block **542**. If it is determined that the DCV and/or economizer system **130** requires calibration, and in some illustrative embodiments, the controller **302** may disable all compressor stages **506** for the duration of the calibration process. The controller **302** may then check the return air temperature sensor **508** for a valid return air temperature reading. Next, controller **302** may determine the temperature differential **314** between the return air temperature and the outdoor air temperature. In order for the illustrative damper calibration process **500** to continue **516**, the temperature differential must meet the requirements (e.g. greater than 10° F.), and the current conditions must be better than the conditions under which the previous calibration occurred. If either of these is not true, the controller **302** does nothing and the damper calibration process is ended at block **542**.

If the current conditions meet the requirements **516**, the controller **302** may check for an optional expansion module **518**. In some instances, an optional expansion module **518** may provide extended input/output capabilities to the controller. For example, an expansion module **518** may allow for multiple fan speeds (for example, but not limited to, high and low fan speeds). If an expansion module **518** is present, the controller **302** may then check the fan speed **520** of the HVAC system **102**. If the fan speed is set to low, the controller **302** may compute the percent of ventilation necessary **524** for both Va and Vbz at low fan speed (VaLS and VbzLS, respectively). The percent of ventilation at low fan speed may be calculated by the following equations:

$$VaLS = Va\_CFM/MAX\_CFM\_LS \qquad \{Equation\ 2\}$$

$$VbzLS = Vbz\_CFM/MAX\_CFM\_LS \qquad \{Equation\ 3\}$$

where VaLS is the percent of ventilation for minimum building occupancy at low fan speed, Va_CFM is the volume (in cubic feet per minute) of air flow needed to meet the minimum ventilation requirements, VbzLS is the percent of ventilation for maximum building occupancy at low fan speed, Va_CFM is the volume (in cubic feet per minute) of air flow needed to meet the maximum ventilation requirements, and MAX_CFM_LS is the maximum amount of air volume (in cubic feet per minute) the fan can provide at low fan speed.

If the fan speed is not low, or an expansion module **518** is not connected, the controller **302** may compute the percent of ventilation necessary **522** for both Va and Vbz at high fan speed (VaHS and VbzHS, respectively). The percent of ventilation at high fan speed may be calculated by the following equations:

$$VaHS = Va\_CFM/MAX\_CFM\_HS \qquad \{Equation\ 4\}$$

$$VbzHS = Vbz\_CFM/MAX\_CFM\_HS \qquad \{Equation\ 5\}$$

where VaHS is the percent of ventilation for minimum building occupancy at high fan speed, Va_CFM is the volume (in cubic feet per minute) of air flow needed to meet the minimum ventilation requirements, VbzHS is the percent of ventilation for maximum building occupancy at high fan speed, Va_CFM is the volume (in cubic feet per minute) of air flow needed to meet the maximum ventilation requirements, and MAX_CFM_HS is the maximum amount of air volume (in cubic feet per minute) the fan can provide at high fan speed.

Once the percent of ventilation for Va and Vbz has been determined, the controller **302** may check if the minimum damper positions have been determined at block **526** to achieve the desired mixed air temperature (MAT) for Va. If the damper positions have not been determined, the controller **302** may compute **532** the mixed air temperature for Va given the sensed return air temperature, outside air temperature and the desired percent of ventilation Va. The controller **302** may then adjust the intake and/or exhaust dampers **122**, **120** until the required MAT has been reached, as indicated at block **534**.

The corresponding damper position may be saved within a memory of the controller **302**.

Once the damper position has been determined for Va, the controller **302** may determine if a validation recheck **528** of the return air temperature and temperature differential (RAT–OAT) has been performed. In some instances, the damper calibration process **500** may be iterative such that the calibration process **500** is cycled through until the damper position has been determined for both Va and Vbz at a high fan speed and a low fan speed (if available). In some instances, the damper positions for Va may already be determined when the controller **302** arrives at the decision block **526** for Va damper position. In this instance, the controller may not determine the damper position, but instead may check if a validation recheck **528** of the return air temperature and temperature differential (RAT–OAT) has been performed in order to help ensure that the calibration has been completed under suitable conditions. If a recheck **528** has not been performed, the dampers **120**, **122** may be closed and the conditions may be verified by beginning the temperature sensor checks **508** again. In some embodiments, the calibration of the damper positions **532**, **534**, **436**, **538** may be performed with an Adaptive Intelligent Action (AIA) function block.

If the recheck **528** has been performed, the controller **302** may compute **536** the mixed air temperature for Vbz. The intake damper **122** may be opened at shown at block **538** until the required MAT has been reached. The corresponding damper positioned may be saved within a memory of the controller **302**. Once the damper position has been determined for Vbz, the controller **302** may return control of the dampers for normal system operation **540**, at which point the calibration process **500** is complete as shown at block **542**. As discussed above, the calibration process **500** may be performed at, for example, system boot up, at a predetermined frequency, upon user initiation through a test and calibration mode, and or at any other suitable time as desired.

Those skilled in the art will recognize that the present invention may be manifested in a variety of forms other than the specific embodiments described and contemplated herein. Accordingly, departure in form and detail may be made without departing from the scope and spirit of the present invention as described in the appended claims.

What is claimed is:

1. A Demand Control Ventilation (DCV) and/or Economizer system that is configured to be attached to a roof top HVAC unit of a building, comprising:

a DCV and/or economizer unit having a damper and a controller integrated with and located at the DCV and/or economizer unit, wherein the controller includes a memory, and wherein the damper is configured to selectively control air flow from outside of the building and into the building;

the controller is configured to control a position of the damper such that a desired air flow of outside air is drawn into the building;

the memory of the controller storing one or more calibration parameters generated during a commissioning of the DCV and/or economizer unit, wherein the one or more calibration parameters includes a minimum damper position based on a desired non-zero ventilation rate of the building;

an interface for retrieving one or more of the stored calibration parameters from the memory of the controller of the DCV and/or economizer unit for display to a user, and for receiving a command from a user to initiate and perform one or more user initiated tests of the DCV and/or economizer unit; and

wherein the controller is configured to initiate and perform one or more tests of the DCV and/or economizer unit upon receiving the command from the user via the interface, the one or more tests comprising proving that the damper can successfully be moved from a first position to a second position and providing confirmation to the user.

2. The Demand Control Ventilation (DCV) and/or Economizer system of claim **1**, wherein one of the stored calibration parameters includes a date of commissioning parameter.

3. The Demand Control Ventilation (DCV) and/or Economizer system of claim **1**, wherein one of the stored calibration parameters includes a person or company parameter.

4. The Demand Control Ventilation (DCV) and/or Economizer system of claim **1**, wherein one of the stored calibration parameters includes a minimum damper position parameter.

5. The Demand Control Ventilation (DCV) and/or Economizer system of claim **1**, wherein one of the stored calibration parameters includes a maximum damper position parameter.

6. The Demand Control Ventilation (DCV) and/or Economizer system of claim **1**, wherein one of the stored calibration parameters includes an airflow parameter.

7. The Demand Control Ventilation (DCV) and/or Economizer system of claim **1**, wherein the memory is a non-volatile memory.

8. The Demand Control Ventilation (DCV) and/or Economizer system of claim **1**, wherein the interface includes a local user interface.

9. The Demand Control Ventilation (DCV) and/or Economizer system of claim **1**, wherein the interface includes a remote user interface.

10. The Demand Control Ventilation (DCV) and/or Economizer system of claim **1**, wherein the interface includes a wired interface.

11. The Demand Control Ventilation (DCV) and/or Economizer system of claim **1**, wherein the interface includes a wireless interface.

12. The Demand Control Ventilation (DCV) and/or Economizer system of claim **1**, wherein the controller includes a test mode, wherein in the test mode, a user can independently control a position of the damper.

13. The Demand Control Ventilation (DCV) and/or Economizer system of claim **1**, wherein the memory of the controller in a non-volatile memory, and the stored calibration parameters are stored in non-volatile memory, and wherein the controller is programmed to downloaded the stored calibration parameters to a remote device via the interface upon request.

14. The Demand Control Ventilation (DCV) and/or Economizer system of claim **1**, wherein the controller is programmed to automatically initiate and perform one or more self-tests of the DCV and/or economizer unit.

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